DSN Wideband Data Subsystem

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This article describes the Wideband Data Subsystem (WBS) of the Ground Communications Facility (GCF), which greatly increased the data yield and provided near-real-time video pictures during the Mariner 10 flyby of the planets Venus and Mercury.

I. Introduction

A. General

When Columbus discovered America, Queen Isabella had to await his return to learn where he had gone and what he had found. Even though our spaceships travel far greater distances than did Columbus' ships, we can almost instantaneously obtain the kind of information from them that Isabella had to wait months for. The current state of the art of deep space exploration does not provide for the return of an exploratory vehicle; therefore, we must depend upon communication with it to obtain its scientific and engineering data.

The purpose of this article is to review the Deep Space Network (DSN) Wideband Data Subsystem (WBS) of the Ground Communication Facility (GCF) that enabled us to greatly increase the data yield and provide near-real-time video (TV) pictures during the Mariner 10 flyby of the planets Venus and Mercury. Although much information was gained by the video pictures from the cloud-shrouded Venus, the spectacular video mapping of the planet Mercury was made possible by the increased data rate. TV pictures of the Mercury encounter were displayed on a large screen in near-real-time at both JPL and NASA Headquarters in Washington, D. C.

B. Deep Space Network Description

To discuss the wideband data link we must first understand how it fits into the total picture of tracking and data acquisition. The tracking and data acquisition system for communicating with spacecraft beyond the moon (Earth to the moon is referred to as near-space) is the DSN. The DSN communicates with spacecraft from Deep Space Station (DSS) locations on Earth approximately 120 deg apart in longitude, two in north and one in south latitudes. These complexes are located near Madrid, Spain, Canberra, Australia, and Goldstone, California. The general DSN configuration is shown in Fig. 1.

The Network presently consists of one 64-meter antenna subnet and two 26-meter antenna subnets. Each subnet includes three antennas, one at each location. These installations are known as Deep Space Stations. The spacecraft data are transmitted and received via the antennas at the DSSs and processed and sent via telecommunication systems to JPL in Pasadena for processing and dissemination as specified by the mission plans. The facilities at JPL provide necessary data to the DSSs for tracking and commanding the spacecraft by the reverse procedure.

C. Ground Communications Facility

Communications between JPL and the DSSs is accomplished through the GCF. The 1973–1974 routing of the interconnecting GCF network is shown in Fig. 2. The total communications system consists of combinations of series and parallel routings using communication satellites, microwaves, landlines, underwater (submarine) cables and radio for redundancy and reliability. NASA Communications (NASCOM) leases the long-line links and data sets and provides switching at Goddard Space Flight Center (GSFC) Greenbelt, Maryland, and other locations as noted in Fig. 2.

II. Wideband Data Subsystem

A. General

The Wideband Data Subsystem is primarily implemented in the 64-meter (210-ft) antenna subnet. Figure 3 is a simplified block diagram of this subsystem. It includes lines to the Compatibility Test Area at JPL (CTA 21) and the Spacecraft Compatibility/Monitor Station at Merritt Island (STDN MIL). These were included on the block diagram because of their use in testing the WBS with the spacecraft and will not be discussed further. NASCOM GSFC is the NASA switching center at the Goddard Space Flight Center in Greenbelt, Maryland, and FDX indicates full duplex system (also denoted by double-arrowed lines).

The key design characteristics of the DSN GCF Wideband Subsystem are:

(1) Permanent terminal equipment with circuits activated only when wideband data rates are needed, thus reducing lease costs.

(2) Transmission rates of 28.5 and 50 kilobits per second (kbps) with bit error rates of 5×10^{-5} or better.

(3) Standard 1200/2400-bit block format with better than 97% of all blocks delivered error-free in real time.

(4) Transmission error detection for all DSS circuits but no error correction.

(5) Rapid semi-automatic recall.

(6) Full demultiplexing at DSS and Central Communications Terminal to provide only requested data to each user.

(7) Provision of subsystem real-time status to GCF Monitor and Control Subsystem (manual during Mariner Venus/Mercury 1973).

(8) Project remote terminal equipment not supplied by GCF.

(9) Nonstandard (open) formats may be used on project circuits, but such circuits are not automatically monitored nor will errors be detected by GCF.

(10) 33-bit error polynomial provides positive error detection.

(11) Block synchronous data transmission.

(12) Receive timing provided continuously.

Although it is used primarily for the 64-meter subnet, the WBS can support one 26-meter antenna station at Australia and one 26-meter antenna station at Spain because of a design commonality. Permanent wideband terminal equipment is installed at Australia and Spain, but the circuits are activated only when required to support a mission and its associated testing. There is permanent wideband interconnection from JPL to Goldstone via a leased microwave link. This basic capability operates at 28.5 kbps. It will be upgraded to 50 kbps to support the Viking program in the 1976–1977 era. Redundant 230-kbps microwave super group circuits were installed to DSS 14 only to accommodate the Mariner 10 Venus and Mercury encounters, enabling the spacecraft to transmit data at 117.6 kbps during the critical encounter time periods. A TV circuit was leased to transmit the near-real-time video picture of the Mercury encounter from JPL, Pasadena, to NASA Headquarters in Washington, D.C.

Additionally, two 230-kbps super group wideband circuits will be permanently activated from the JPL Central Communication Terminal to the Network Operations Control Center. Currently, 50-kbps wideband circuits are being used.

As a result of the expansion of the WBS a coded multiplexer/demultiplexer (CMD) assembly is used to accomplish the equivalent functions of a block detection decoder and block demultiplexer. This device is smaller and less costly than the previously used individual units (4) and can operate at the rate of 250 kbps and higher, accommodating block lengths of 1200, 2400 and 4800 bits.

Figure 4 provides a more detailed diagram of the Wideband Subsystem being used during the Mariner 10 mission. Redundant lines and/or switches are provided as required to assure that the data can be received in real time.

B. 28.5-kbps Wideband Capability

The basic wideband data capability for the operation of the Deep Space Network during MVM'73 is 28.5 kbps. All equipment is permanently installed in the network. The Goldstone–JPL microwave link and the hard-wired circuits to the Compatibility Test Area (CTA 21) at JPL are permanently maintained. The circuits between the overseas stations and JPL are activated as required a sufficient time prior to the mission for the support of testing and are maintained throughout the mission. The WBS utilizes the present standard DSN 1200 bit-blocked data while the Mariner 10 project support data transmissions utilize a non-blocked word-formatted data transmission mode. For wideband terminal equipment configurations refer to Figs. 5–7.

C. 50-kbps Wideband Capability

The 50-kbps wideband data rate is a requirement for future deep space missions. Initially, it is planned for support of the Viking program during orbit and lander operations in 1976 and for the Mariner Jupiter/Saturn mission commencing in 1977 at the overseas stations only, since Goldstone GCF super group will be operating at 230 kbps for Mariner Jupiter/Saturn.

During 1971, a lengthy wideband data test was conducted between JPL and the NASCOM Madrid Switching Center in Spain. The purpose of this test was to determine if the error rates of a circuit are generally comparable to those which were expected for the 28.5-kbps circuits planned for Mariner 10 support and to determine the statistical distribution of the errors. The test was successful and the data satisfied both purposes.

The configuration of the circuit used during this test is shown in Fig. 8. A circuit (GW-58619) was provided by NASCOM and consisted of 303 C data sets operating at 50 kbps. The routing of this American Telephone and Telegraph circuit was not known nor were the facilities from which it was derived. The 303 C data set required substantially all of the 48-kHz passband; hence a group bandwidth was used. The routing overseas was via communication satellite as shown in Fig. 8.

Test data consisted of 2047-bit pseudorandom bit pattern generated by Fredrich Electronic Company Model 600 test sets. At each receive location the pseudorandom pattern was also synchronized and compared against the test sets. The tests indicated that the bit error rate may be expected to be 6×10^{-5} or better measured on a long-term basis.

D. 230-kbps Wideband Subsystem, Mariner 10

The GCF 230-kbps wideband capability during the Mariner 10 project consists of one full duplex super group transmission path from DSS 14 (64-meter station at Goldstone) to the JPL Central Communication Terminal (CCT), then to the project computer interface. This wideband channel supported the real-time transmission of the Mariner 10, 117.6-kbps, high-rate telemetry data. The telemetry data were transmitted in a non-blocked, word-formatted mode and no specific GCF monitoring was provided. The GCF wideband super group capability was provided over existing 8-MHz radio channels of the DSS to the complex switching center (GCF 10), then via a 230-kHz super group wideband channel between Goldstone and JPL over Western Union leased microwave equipment. This capability was provided from July 1973 through April 1974 for the Venus and Mercury encounters and during August and September 1974 for the second Mercury encounter. Figures 9–11 illustrate this configuration from the incoming kbps signal through:

(1) Project symbol synchronizer assembly (SSA) word formatter switch.

(2) Project word formatter/deformatter.

(3) Wideband digital patch panel.

(4) General Electric TDM-522 data set MODEM (digital-to-analog converter and data regenerator).

(5) Wideband audio patch panels at DSS.

(6) Wideband analog patch panel (Goldstone Comm Terminal).

(7) General Electric TDM-501 data set.

(8) General Electric TDM-520 data MODEM.

(9) Western Union leased full duplex microwave between Goldstone and JPL.

(10) General Electric TDM-520 data MODEM.

(11) General Electric TDM-501 data set.

(12) DC patch panel.

(13) Patch panels and cables.

(14) Project word formatter/deformatter.

The GCF 230-kbps system experienced almost no technical or installation problems and performance exceeded all expectations. The bit error rate was equal to 1×10^{-5} or better for a 99% throughput during the Venus and Mercury encounters.

E. Network Operations Control Center Wideband Data Link

The Network Operations Control Center (NOCC) is being implemented in three stages. All configurations include a wideband data link from the JPL Central Communications Terminal (CCT) to the data processing equipment in the Network Data Processing Area. These locations are in different buildings approximately 600 meters apart. Figure 12 is a block diagram of the 50-kbps wideband system presently in operation. The system will be upgraded to a 230-kbps super group during the 1975–1976 time period.

The NOCC receives data by tying into the prime line between the DSSs and the project processing equipment. Two PDP-8 computers are located in the Network Data Processing Terminal adjacent to the GCF Communications Terminal at JPL. One of the PDP-8's is prime. Inbound data undergo serial-to-byte transformation in an external receive communications buffer. High-speed and wideband data are routed to the receive communications buffer and then buffered in the PDP-8 to await multiplexing onto the 50-kbps wideband circuit. Filler blocks are rejected rather than multiplexed. After multiplexing, the high-speed and/or wideband blocks are placed in a second buffer to be clocked out to the wideband data line to the Network Data Processing Area (NDPA). External to the PDP-8, byte-to-serial conversion occurs and, as required by the wideband data lines, a voltage-to-current conversion occurs. Multiple high-speed data lines are thus buffered onto a synchronous circuit. To accommodate this operation, the PDP-8 generates a control message for the NDPA computer (Xerox Sigma-5) which precedes each high-speed block multiplexed onto the wideband line. Outbound data are routed essentially the reverse of inbound.

The detailed block diagrams of both the Block I NDPT configuration and the Block I NDPA configuration are shown in Figs. 13 and 14, respectively. The PDP-8 and the Sigma-5 are interconnected by General Electric 401 data sets at either end of the wideband data lines.

III. Conclusions

The GCF Wideband Data Subsystem used in the Deep Space Network is unique in that it is wholly dedicated to transmitting data received by a ground antenna from a spacecraft and providing these data to the processing computers at JPL in real-time with very high reliability. Terminals are provided as permanent installations and lines to overseas stations are leased when required to support specific missions. A variety of data sets, modems, converters, switches, switching centers, test equipment, jack panels and ancillary equipment are provided. A follow-up paper would be useful to describe this equipment in detail, including inputs, outputs, functions and theory of operations; however, these details are not a part of this report.

Even though the Wideband Data Subsystem is unique in that it is fully committed to the DSN, it is similar to commercial systems in that the blocks are formatted and addressed so that each block or series of blocks has an originating location and destination. The theory is compatible with the commercial packet packaging concept if one considers that data can be directed to various locations.

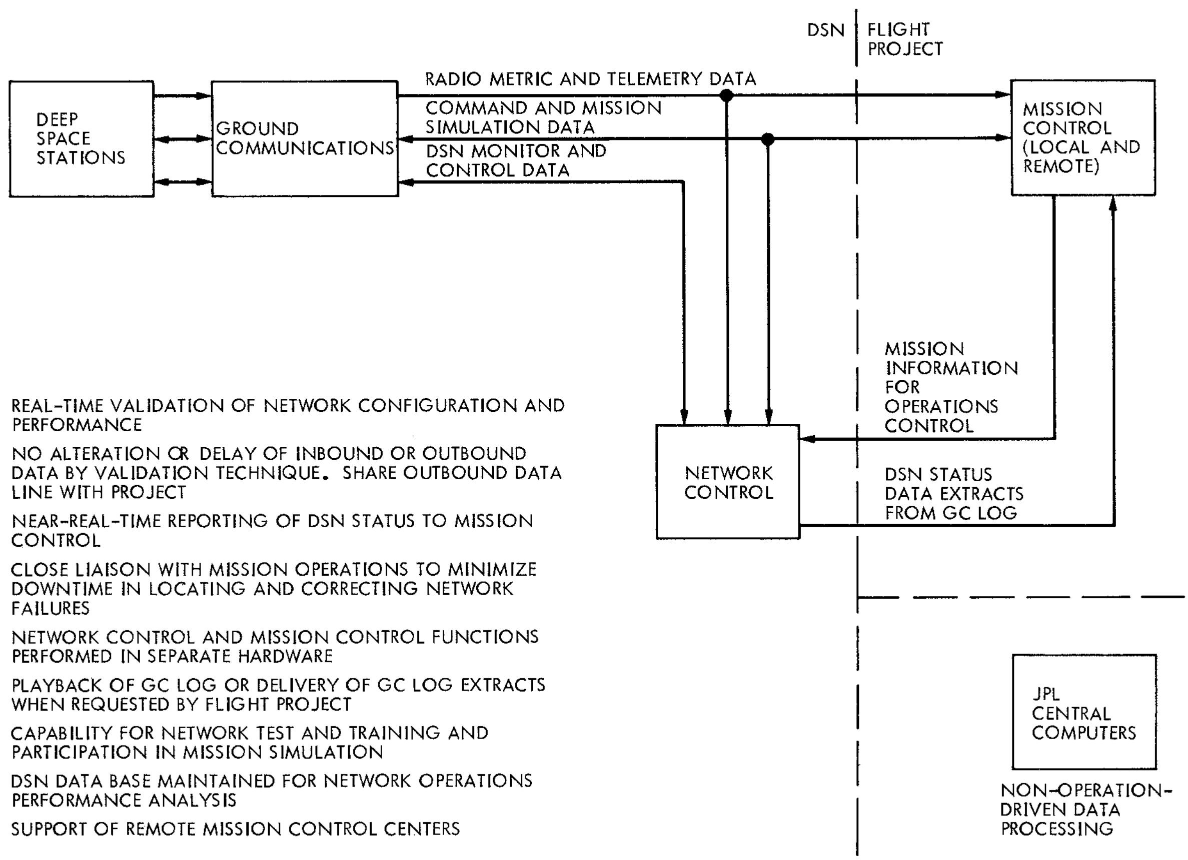


Fig. 1. General configuration of the Deep Space Network

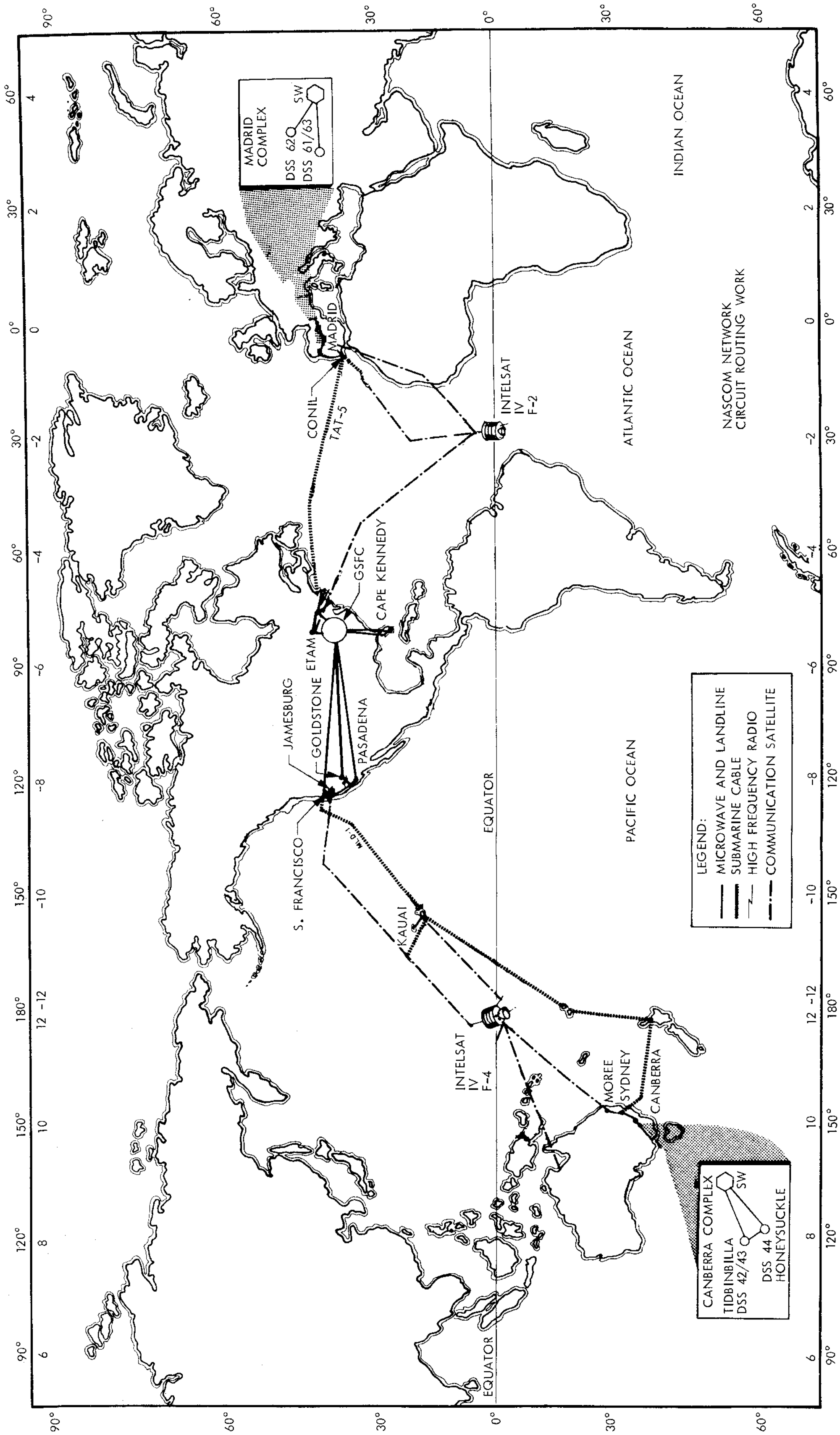


Fig. 2. NASCOM network circuit routing chart

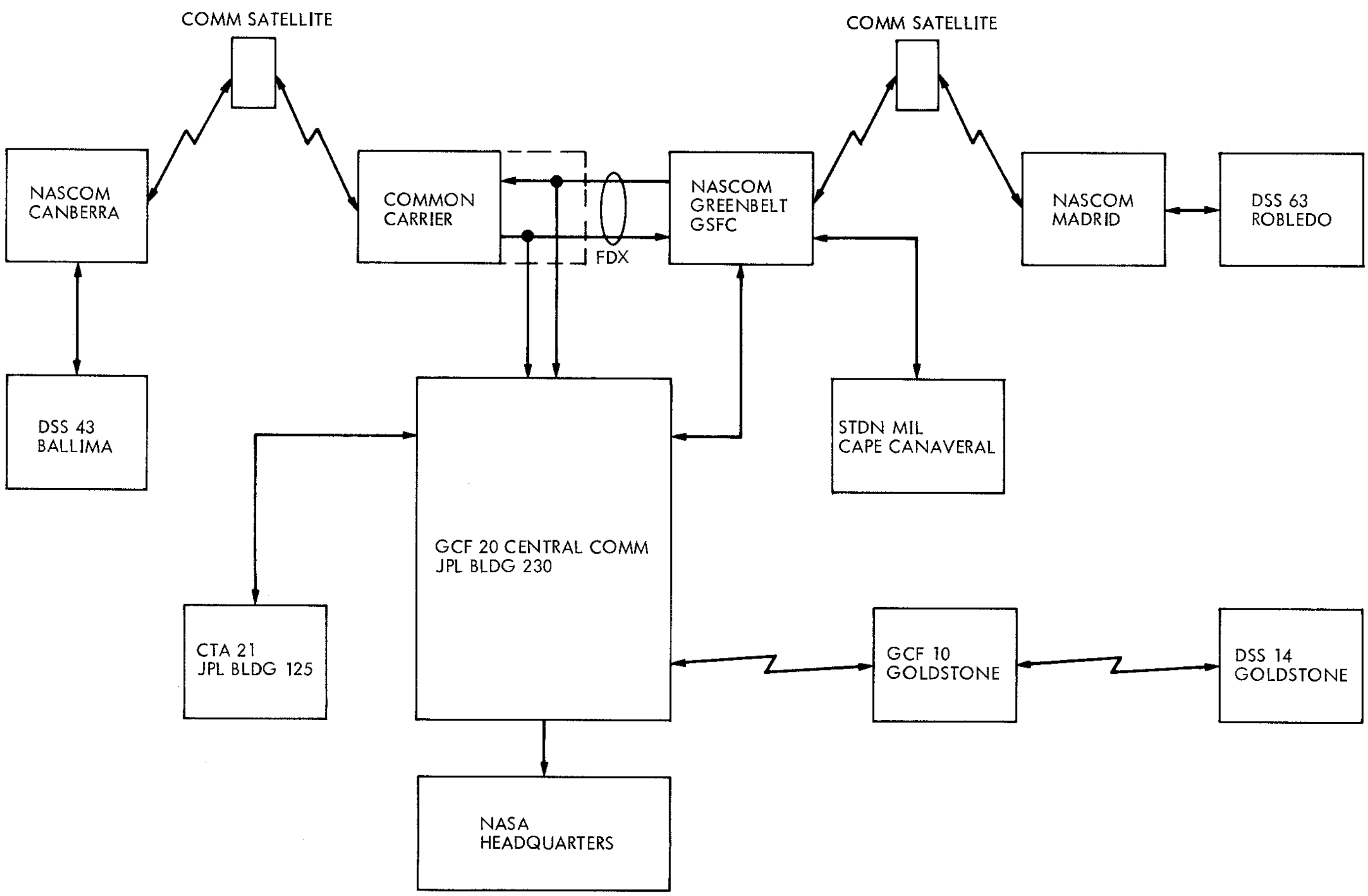


Fig. 3. Wideband Data Subsystem block diagram

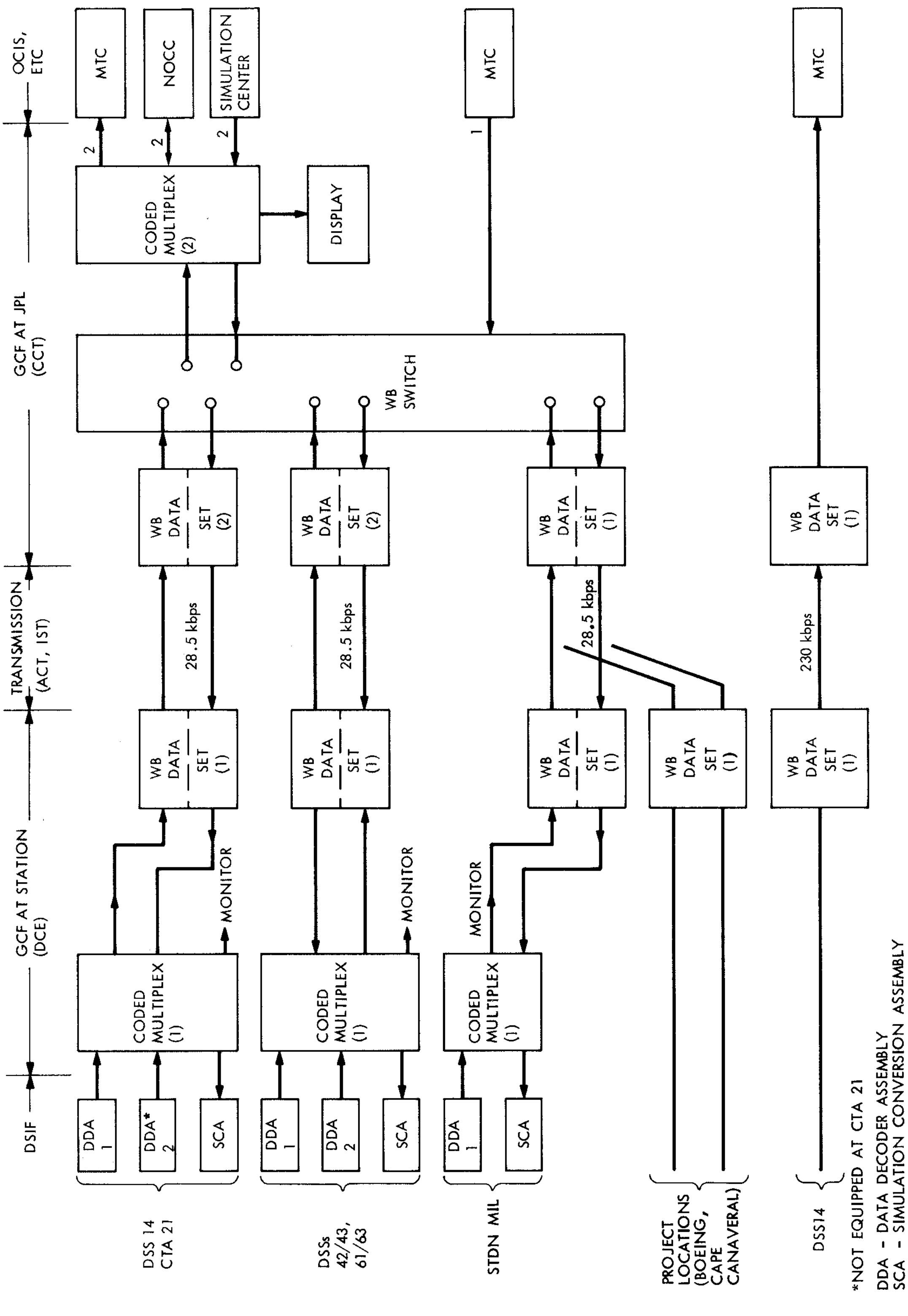
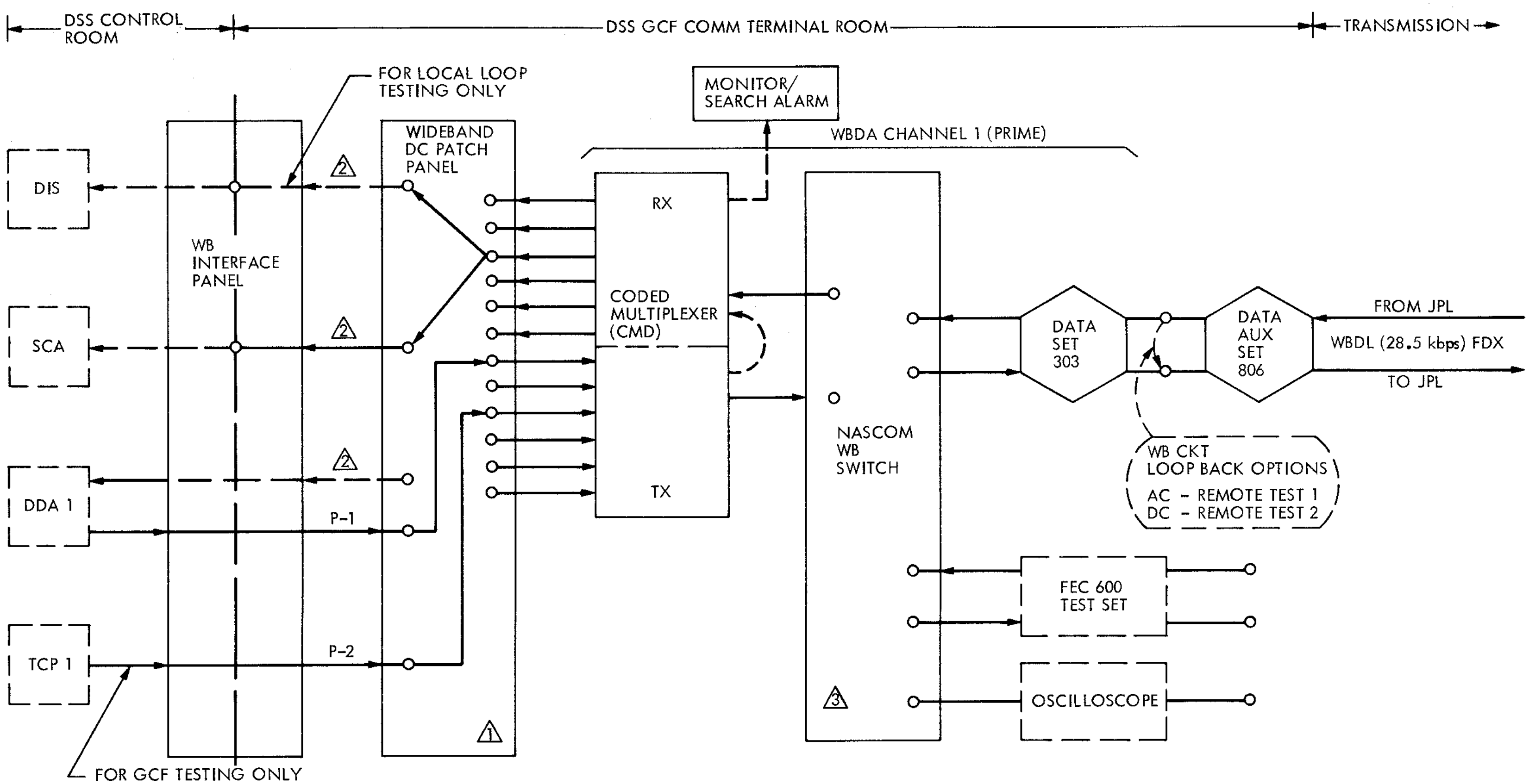


Fig. 4. GCF 1973–1974 wideband data capability



NOTES:

1. STDN MIL AND CTA 21 NOT CONFIGURED WITH CODED MULTIPLEXER SWITCH AND BACKUP WIDEBAND CHANNEL, AND HAVE ONLY ONE DDA WB INTERFACE
2. DIS AND DDA COMPUTER RECEIVE INTERFACES AT DSSs USED IN TEST SUPPORT AND DATA VALIDATION ONLY
3. CTA 21 NOT CONFIGURED WITH NASCOM WB SWITCH

WB EQUIP	DSS 71	CTA 21
DATA SETS (303)	1	1
NASCOM WB SW	1	0
CMDs	1	1

Fig. 5. STDN MIL and CTA 21 GCF (28.5 kbps) Wideband Data Subsystem assembly configuration

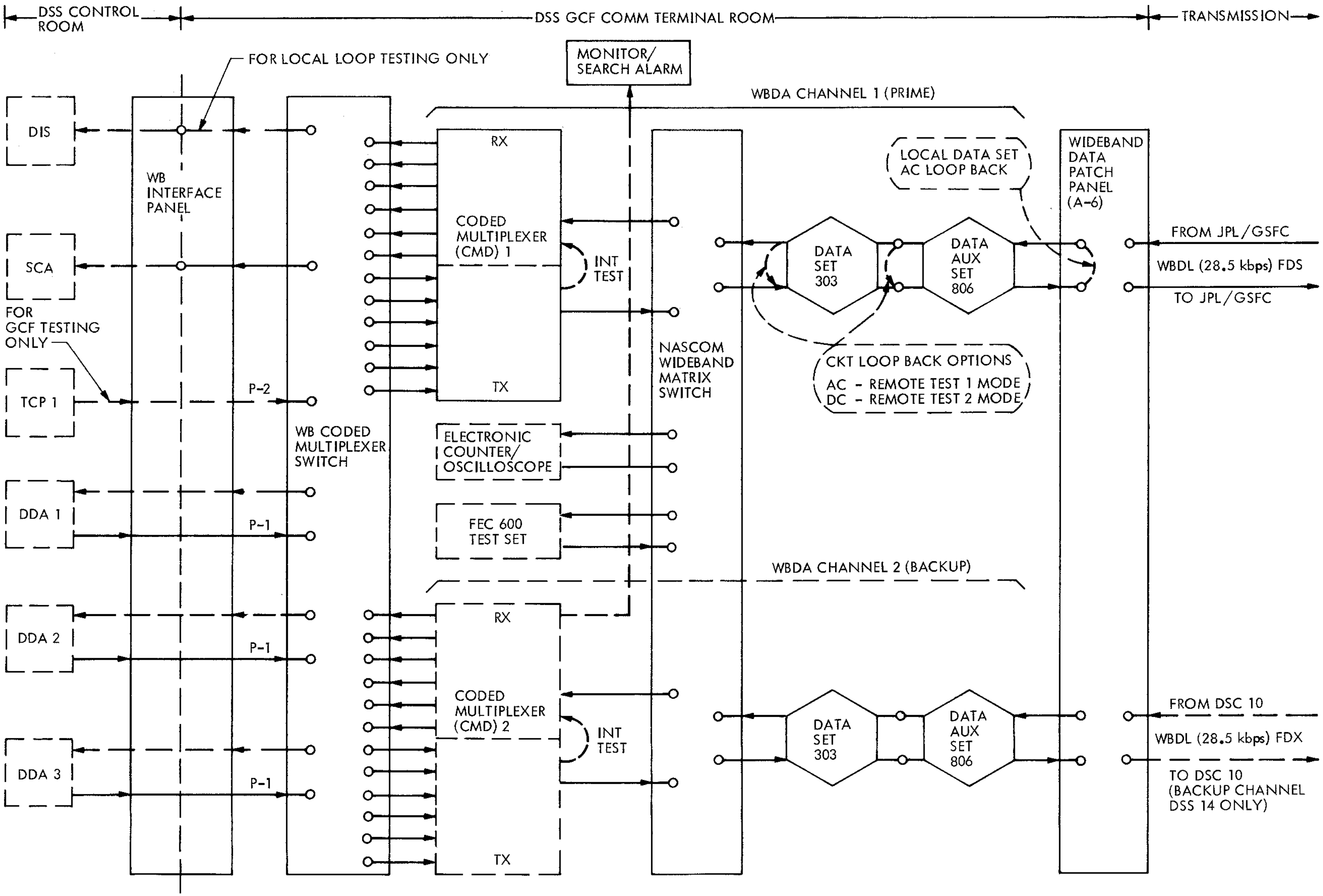


Fig. 6. Deep Space Stations 14/43/63 GCF (28.5 kbps) Wideband Data Subsystem assembly configuration

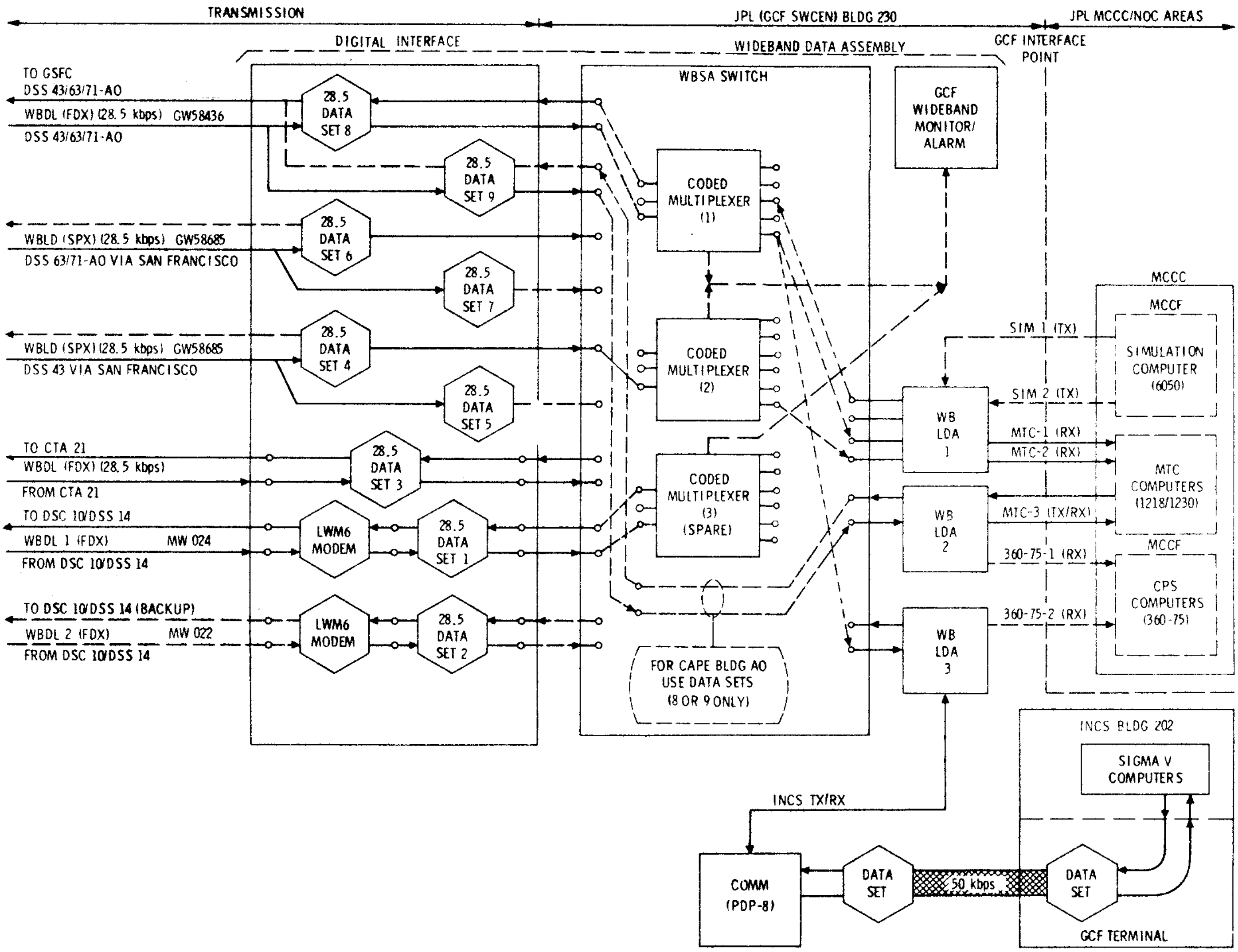


Fig. 7. JPL (GCF SWCEN) (28.5 kbps) Wideband Data Subsystem assembly, MVM'73 configuration

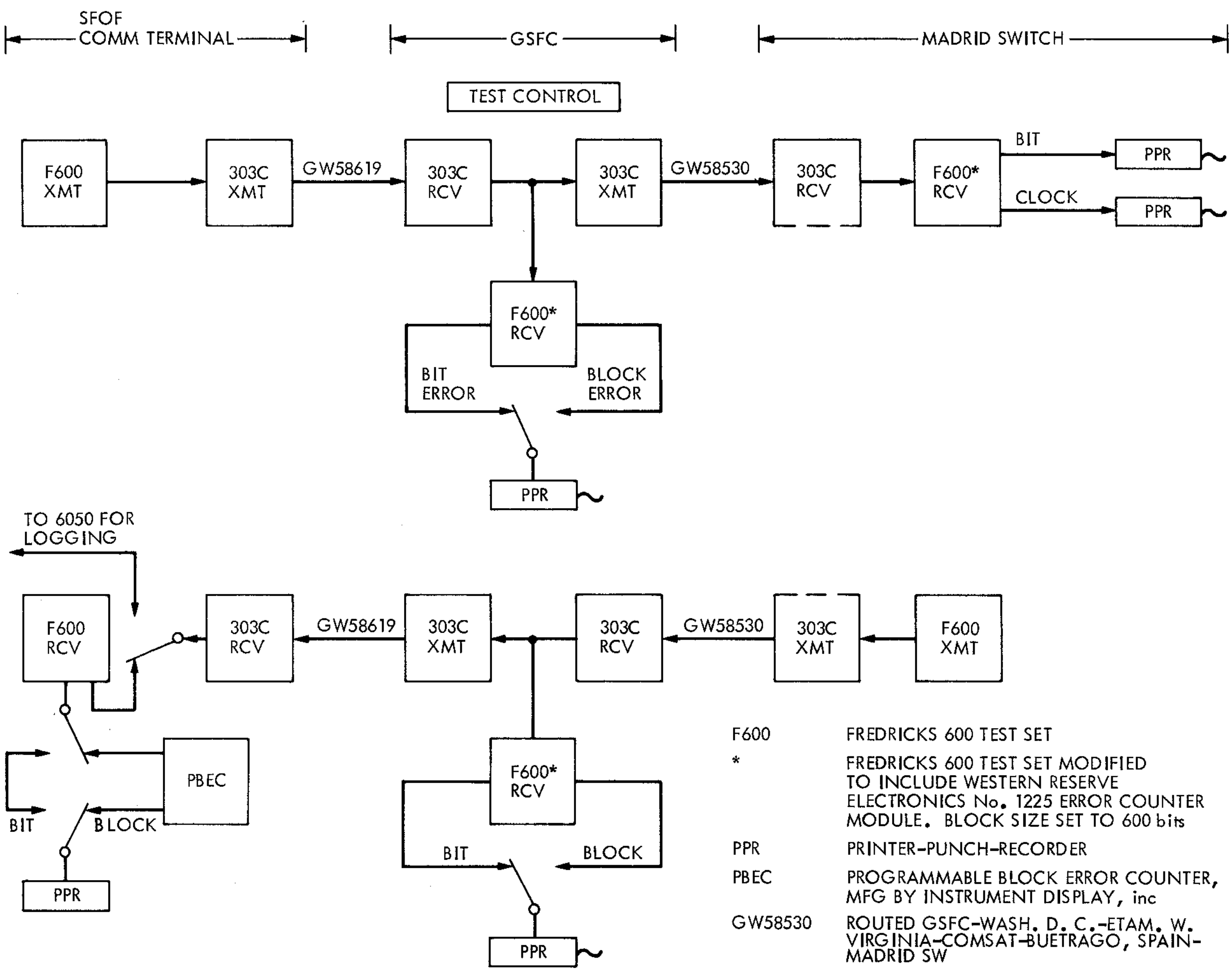
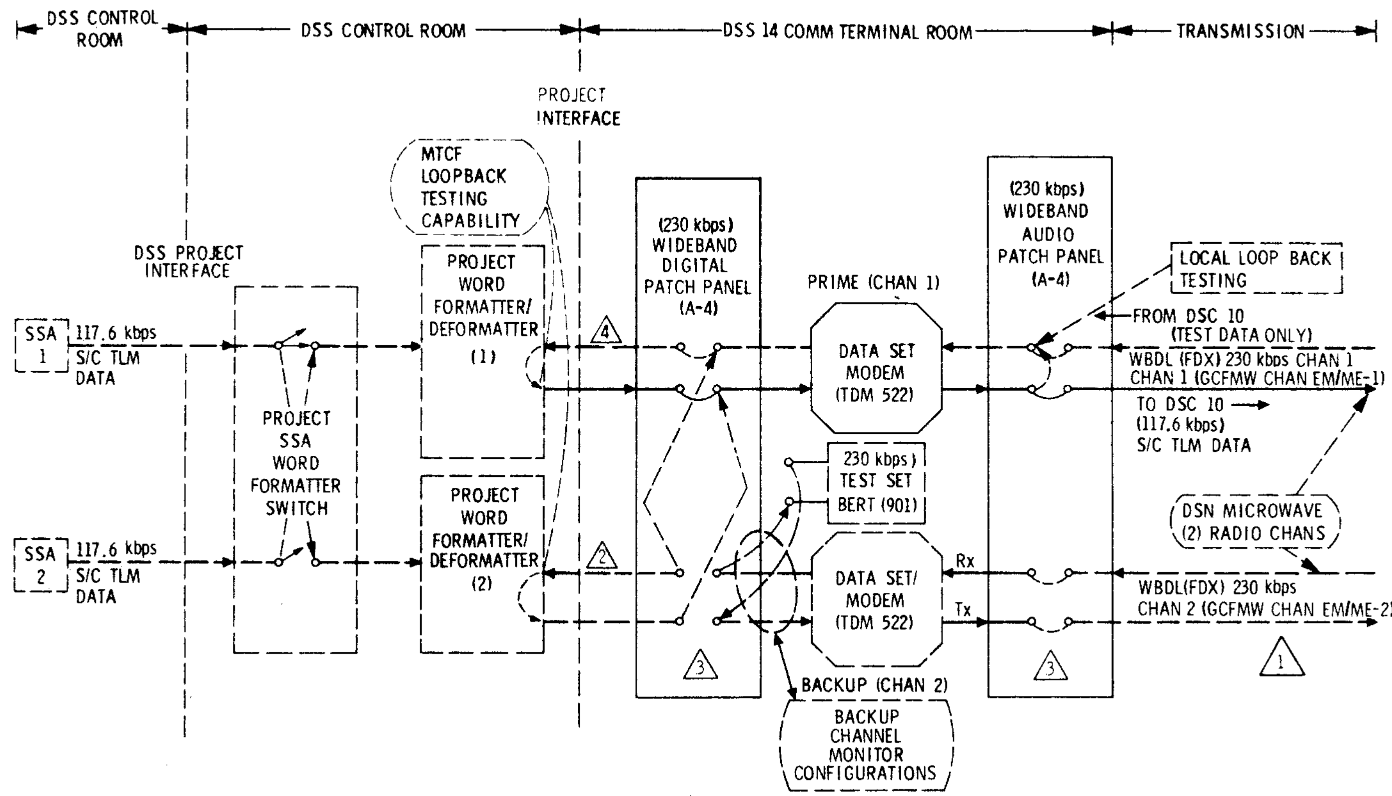


Fig. 8. Wideband Data Subsystem 50-kbps test configuration, June 1971

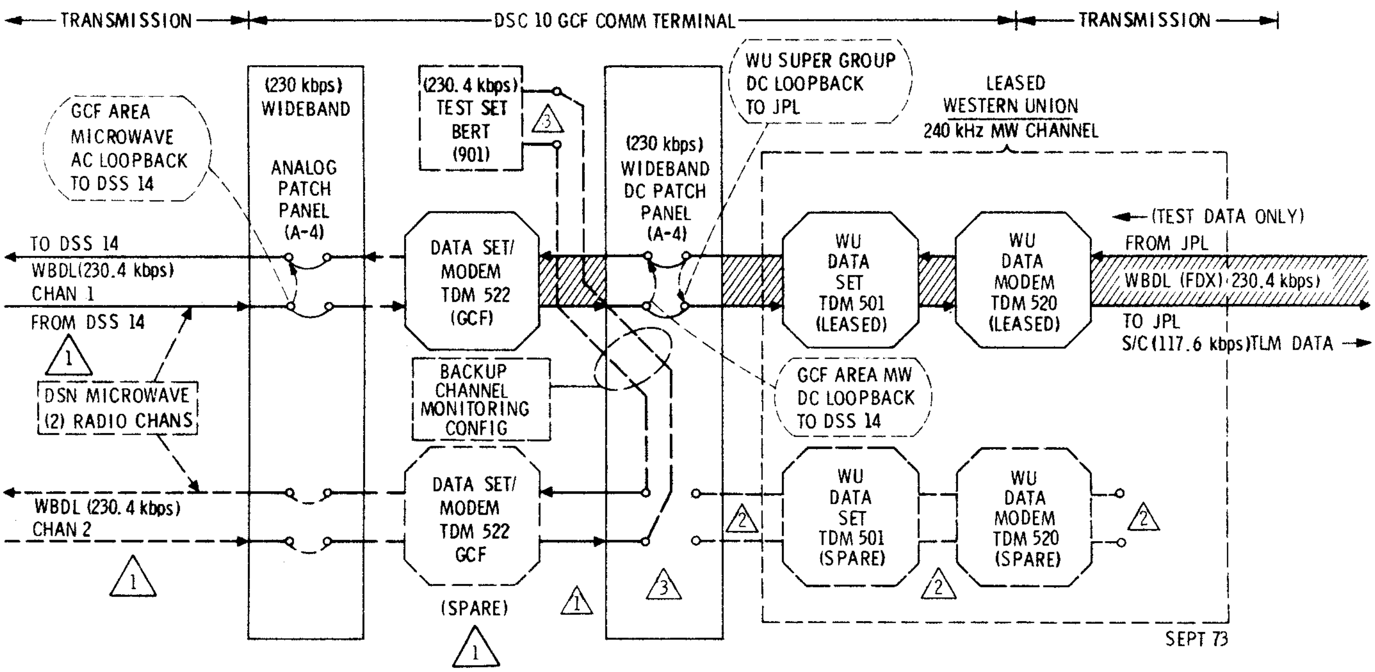


1. GCF (230 kbps) WB CHAN 2 DSS 14 TO DSC 10 WILL NORMALLY BE SCHEDULED AND REMAIN IN HOT BACKUP TEST MODE DURING EACH DSS 14 PASS SUPPORTING 117.6 kbps S/C TLM REALTIME TRANSMISSIONS.

2. FULL DUPLEX LOOPBACK TEST CAPABILITY FROM JPL (MTC COMPUTERS/WORD FORMATTER INTERFACE THRU PROJECT DSS 14 WORD FORMATTERS IS PROVIDED.

3. FOR DETAILED DSS 14 (230 kbps) WB TERMINAL EQUIPMENT CONFIGURATION REFER TO GCF SOP 844-182-10-4109.

Fig. 9. DSS 14 GCF (230 kbps) Wideband Data Subsystem assembly configuration



1. GCF BACKUP 230 kbps WB (CHAN 2) DSC 10-TO-DSS 14 WILL NORMALLY BE SCHEDULED BY GCF AND REMAIN IN HOT BACKUP CONTINUOUS TEST MODE DURING EACH DSS 14 PASS SCHEDULED FOR REALTIME TX OF 117.6 S/C TLM DATA.

2. WU BACKUP DATA SET/DATA MODEM PATCHING TO BE ACCOMPLISHED BY WU PERSONNEL ONLY

3. FOR BACK CHAN DETAILED 230 kbps WB TERMINAL EQUIPMENT CONFIGURATION REFER TO GCF SOP 844-182-10-4109.

Fig. 10. DSS 10 communications terminal GCF (230 kbps) Wideband Data Subsystem assembly configuration

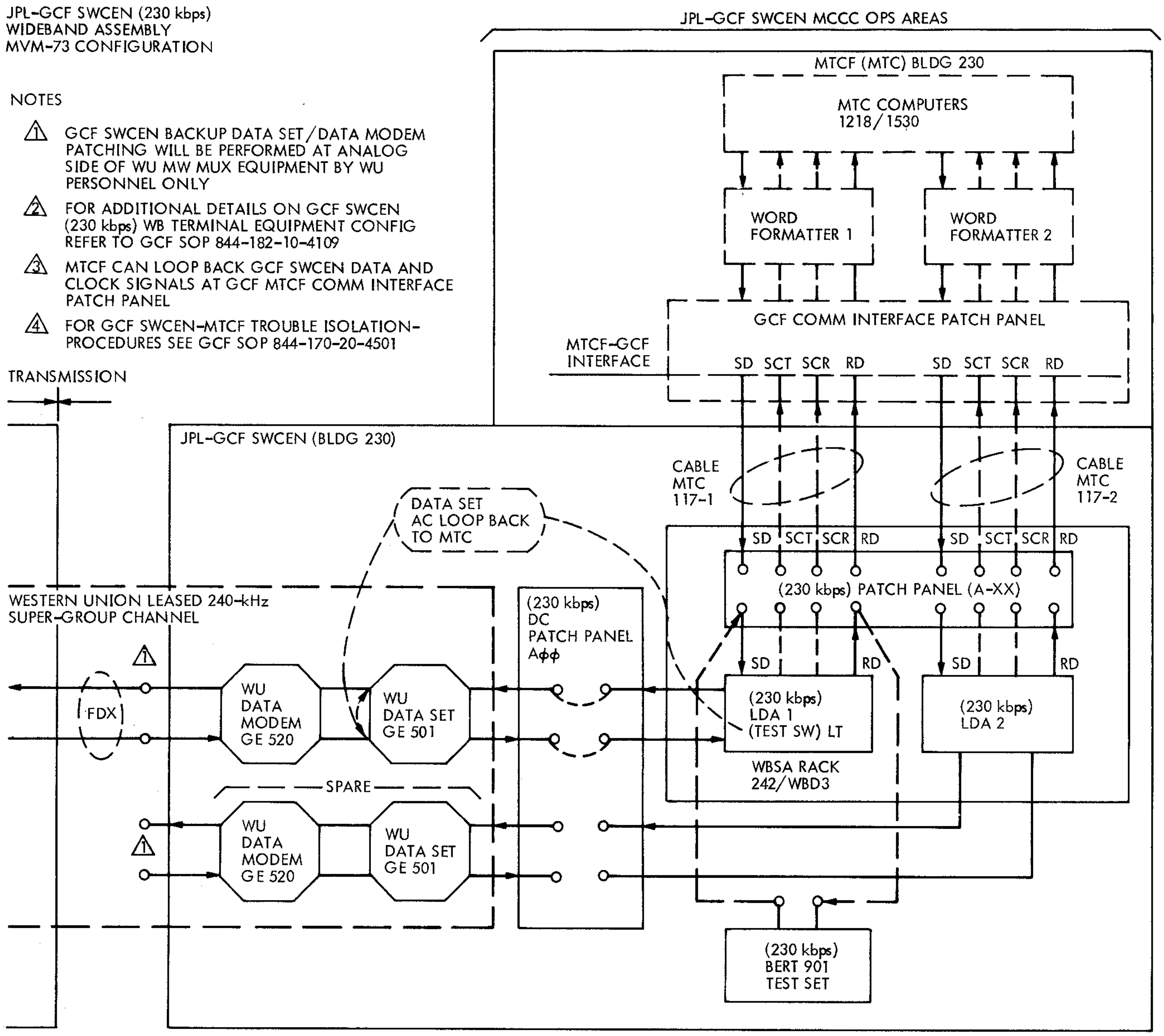


Fig. 11. JPL (GCF SWCEN) (230 kbps) Wideband Data Subsystem assembly configuration

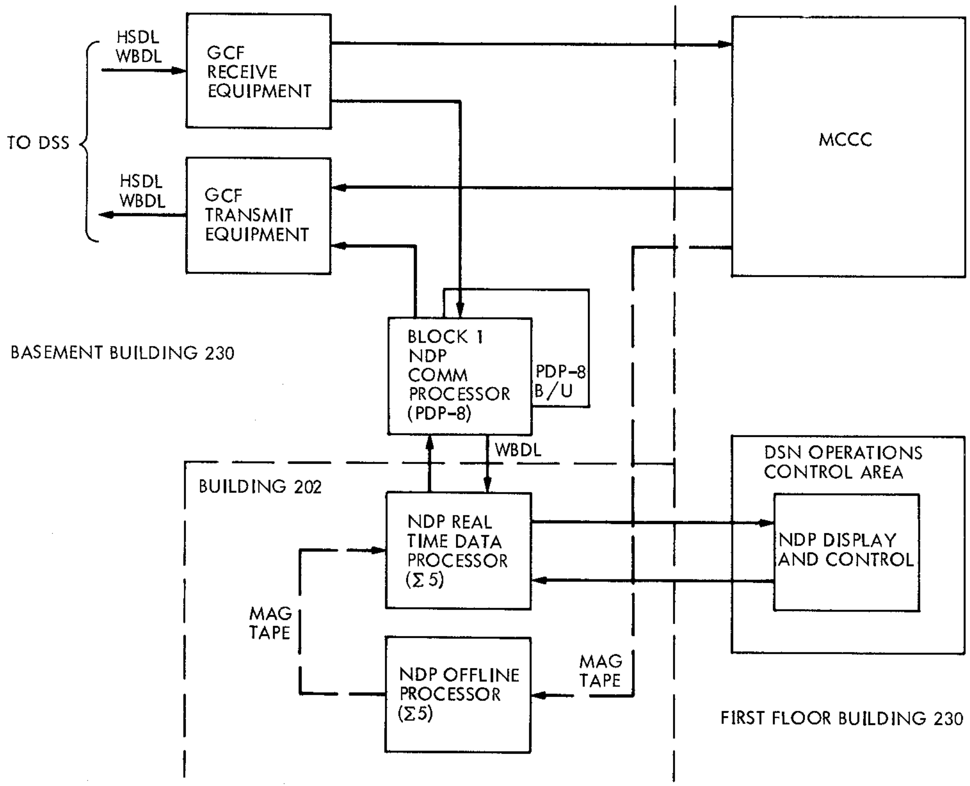


Fig. 12. Block I NDP configuration

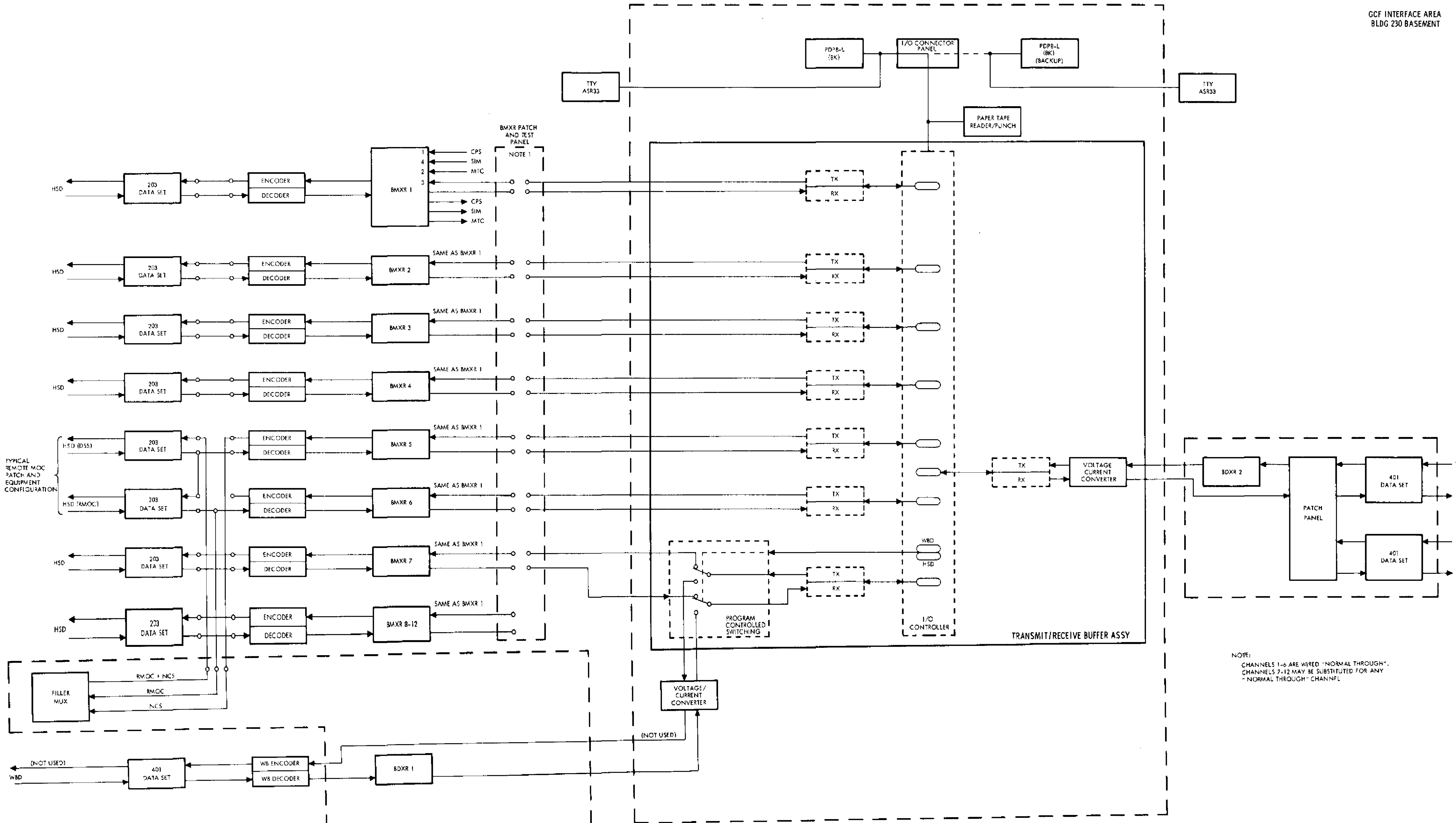


Fig. 13. Block I NDPT configuration

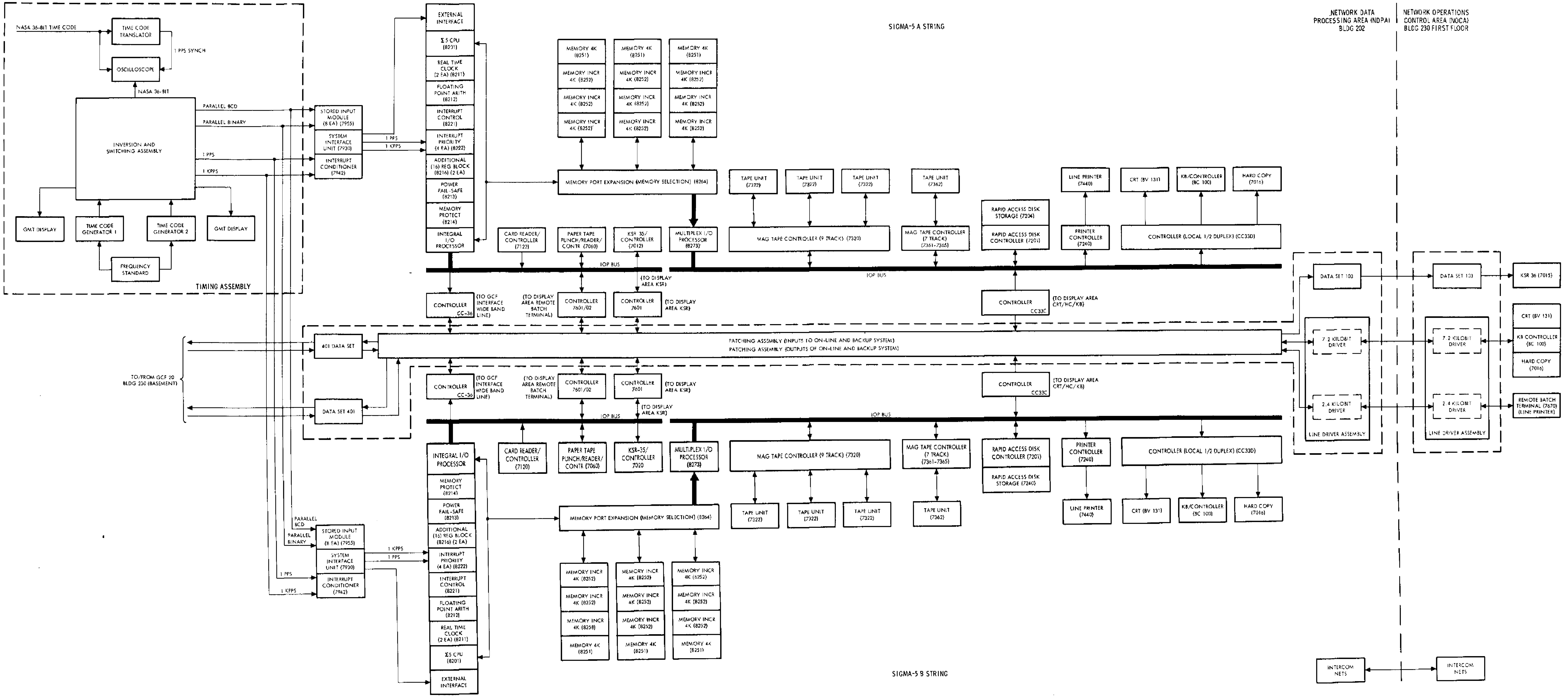


Fig. 14. Block I NDPA block diagram